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Title Page

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Full title: The influence of an artificial playing surface on injury risk and perceptions of muscle soreness in elite Rugby Union.

Running title: Playing elite level rugby on artificial turf.

Abstract

This prospective cohort study investigated the influence of an artificial playing surface on injury risk and perceptions of muscle soreness in elite English Premiership Rugby Union players. Time-loss (from 39.5 matches) and abrasion (from 27 matches) injury risk was compared between matches played on artificial turf and natural grass. Muscle soreness was reported over the four days following one match played on each surface by 95 visiting players (i.e., normally play on natural grass surfaces). There was a likely trivial difference in the overall injury burden relating to time-loss injuries between playing surfaces (rate ratio = 1.01, 90% CI: 0.73-1.38). Abrasions were substantially more common on artificial turf (rate ratio = 7.92, 90% CI: 4.39-14.28), although the majority of these were minor and only two resulted in any reported time-loss. Muscle soreness was consistently higher over the four days following a match on artificial turf in comparison with natural grass, although the magnitude of this effect was small (effect sizes ranging from 0.26 to 0.40). These results suggest that overall injury risk is similar for the two playing surfaces, but further surveillance is required before inferences regarding specific injury diagnoses and smaller differences in overall injury risk can be made.

Key words: Injury incidence, abrasion, skin injury, artificial turf, risk factors.

Introduction

There is a growing interest in the use of artificial turf surfaces in Rugby Union. In particular, artificial surfaces may be a useful means of increasing participation in the sport by allowing greater usage of a given pitch, especially in regions where natural turf pitches are difficult to maintain. During the 2012/13 season, an English Premiership team became the first elite Rugby Union team to install and play matches on an artificial surface, but it is expected that their use by teams across all levels of the game will increase in the future.

Playing surfaces may have a direct (e.g. influencing shoe-surface interactions; Drakos et al., 2013) and/or indirect (e.g. altering running speeds, ball-in-play time and concomitant fatigue levels; Andersson et al., 2008; Di Michele et al., 2009; Gains et al., 2010; Norton et al., 2001) influence upon injury risk. Whilst overall acute injury risk on new generation artificial surfaces in elite football appears to be equivalent to natural grass (Bjørneboe et al., 2010; Ekstrand et al., 2006), the influence of an artificial playing surface on injury risk in elite Rugby Union is currently unclear. Fuller et al., (2010) conducted a two-season investigation comparing match injuries sustained on artificial turf and natural grass by Rugby Union teams competing in the Hong Kong Division 1. The authors reported no significant difference in the incidence of match injuries between the two surfaces. The number of anterior cruciate ligament injuries in matches was notably higher on artificial turf (n=5) compared to natural grass (n=1), but this difference was not statistically significant. However, the study population used from the Hong Kong Division 1 is unlikely to be comparable with that of English Premiership teams, as evidenced by the significant differences in anthropometrics and match injury

incidence between the two populations (Fuller et al., 2010). As such, the results may not be applicable to elite Rugby Union cohorts.

Wounds, burns and friction injuries were reported to be more common on older generations of artificial turfs compared with natural grass (Ekstrand and Nigg, 1989; Gaulrapp et al., 1999). More recently, Ekstrand et al., (2011) reported that such injuries might no longer be a problem when playing football on modern high quality artificial turf pitches. However, skin injuries are likely to be underreported in studies that use time-loss injury definitions (Ekstrand et al., 2006). Moreover, the risk of incurring such acute skin injuries may be higher during Rugby Union matches in comparison with football due to the frequent player-surface interactions, but this is yet to be investigated. Burillo et al., (2012) investigated perceptions of football users (players, coaches and referees) towards third-generation artificial surfaces, and reported that skin abrasions were seen as the biggest disadvantage of artificial turf. Whilst surface-related skin damage injuries are typically minor, they can be problematic if they cover a large area or when foreign materials become embedded in the skin lesion, and the related discomfort may negatively impact on players' performances (Peppelman et al., 2013). As such, there is a need to understand the influence that artificial surfaces have upon the risk of abrasion injuries in elite Rugby Union.

Professional soccer players have reported greater muscle and joint soreness and longer recovery times following matches played on new generation artificial turf (Poulos et al., 2014). An important component in the management of team-sport athletes is the understanding of how players respond to and recover from matches ahead of the subsequent week's training and match demands (Montgomery &

Hopkins 2012). Thus, an understanding of the influence that an artificial playing surface has upon perceptions of muscle soreness in this cohort is required.

This study sought to investigate the influence that a third-generation artificial playing surface has upon time-loss and abrasion injury risk, and perceptions of muscle soreness, in elite Rugby Union players.

Methods

Study design and setting

This was a prospective cohort study of injuries (time-loss and abrasion) and perceptions of muscle soreness following Premiership and National Cup fixtures involving one English Premiership team. The team's home fixtures were played on an artificial turf surface, whilst their away fixtures (on natural grass surfaces) were used for comparison. Data pertaining to both the home and away team were included in the dataset. A pilot study was conducted during the second half of the 2012/13 season (13 matches) to test the appropriateness of the time-loss and abrasion injury data collection methods. A season-long data collection period was then conducted throughout the 2013/14 season (27 matches). Time-loss injury data from both these periods were included in the analysis to maximise statistical power. For abrasion injuries and perceptions of muscle soreness, only data collected throughout the 2013/14 season were included in the analysis. The study design and data collection procedures were approved by the Research Ethics Approval Committee for Health at the University of Bath. Written informed consent was obtained from all players included in the study, and all data were anonymised.

The third-generation sand and rubber filled artificial surface (SIS Rugger 65 mm, Support in Sport, Cumbria) was tested independently to ensure it complied with RFU standards, specifically International Rugby Board (2008) regulation 22. Both laboratory and field tests were conducted to assess the suitability of the artificial surface for Rugby Union in relation to three categories (International Rugby Board 2010): (1) Ball-surface interaction; (2) Player-surface interaction and (3) Durability.

Variables

The definitions and procedures used in this study were consistent with the international consensus statement for epidemiological studies in Rugby Union (Fuller et al., 2007). The primary (time-loss) injury definition used in this study was:

‘Any physical complaint sustained by a player during a first-team match that prevented the player from taking a full part in all training activities typically planned for that day, and/or match play for more than 24 hours from midnight at the end of the day the injury was sustained’.

Additionally, the incidence and nature of all abrasion injuries incurred, regardless of any resultant time-loss, were assessed within 60 min of the completion of each match by an assigned field researcher from the University of Bath. Abrasions were defined as excoriations of the skin produced by acute contact with the playing surface, and were identified by club medical personnel or the assigned research officer. Information pertaining to the size, depth, location and pain induced by each abrasion was recorded. The depth of the abrasion was graded, whereby a ‘first-degree’ abrasion involved damage to the epidermis only, a ‘second-degree’ abrasion involved the epidermis and dermis (and may have induced punctate bleeding and tissue exudate), while a ‘third-degree’ abrasion involved damage to the subcutaneous layer. An abrasion was recorded as an ‘exacerbation’ for cases in which a player reported a worsening in the condition of an index abrasion that had not fully healed. These cases were verified against past recorded abrasion records and/or with medical personnel.

Muscle soreness responses were reported by a sample of opposition players on each of the four days following one match played on the artificial turf surface, as well as one match played on a natural grass surface for comparison. Muscle soreness responses were collected over two consecutive weeks in order to avoid bias relating to the timing of the fixture within the season. The sample was balanced, such that a similar number of players responded having played on the artificial surface first (n=50) as those who played on a natural grass surface first (n=45). On each of the four days following a selected match, players were sent a Short Message Service (SMS) message to which they responded with a number indicating their level of general muscle soreness. Data for players who played less than 30 minutes and/or provided fewer than three comparable responses were excluded from the analysis. The question sent to participants was:

‘Please indicate your level of muscle soreness by replying with a number between 0-5, where 0 signifies ‘no soreness’, 3 signifies ‘a light pain when walking up or down stairs’ and 5 signifies ‘a severe pain that limits my ability to move’.

Statistical methods

Incidence rates were recorded as the number of injuries per 1000 player hours of match exposure. Player match exposures were calculated on a team basis, assuming that each team game involved 15 players and lasted for 80 minutes. Severity was determined by the number of days absence from training or match play. Non-parametric tests were used to compare the severity of injuries, where appropriate. Injury burden was calculated by multiplying injury incidence by mean injury severity. Magnitude-based inferences were used to provide an interpretation of the

real-world relevance of the outcome, based directly on uncertainty in the true value of the effect statistic in relation to a smallest worthwhile effect (Batterham & Hopkins 2006). The smallest worthwhile effect for time-loss injuries was an incidence rate ratio of 1.43 (moderate effect), while for abrasion injuries (which were expected to be more common and less severe) a threshold of 2.00 (large effect) was used (Hopkins 2010), using injuries incurred on natural grass as the reference category. A Pearson correlation coefficient was used to assess the relationship between the weekly rainfall prior to the match and the number of abrasions incurred on the artificial turf.

All estimations pertaining to muscle soreness responses were made using the *nlme* package (Pinheiro et al., 2014) in R (version 2.15.1, R Foundation for Statistical Computing, Vienna, Austria). A mixed linear model was used, with each measure of soreness analysed separately as the dependent variable. Data were processed such that each observation had values representing the identity of the player (95 levels), the number of days since the match (4 levels, represented by integer values of 1-4), and the playing surface (2 levels, natural grass or artificial turf). The fixed effects in the model were the playing surface, the number of days post-match, and an interaction between surface and days post-match. To model the repeated measurements within players, a random effect was included that allowed the effect of time to vary across players. A first-order autoregressive covariance structure was used, such that data points close in time were assumed to be more highly correlated than data points distant in time. Akaike's Information Criterion (AIC) and the -2 Log Likelihood were used to assess and compare the model's goodness of fit. Magnitudes of effects were evaluated using standardization. Specifically, the between-player SD (representing the typical variation in soreness between players on

any given day) was derived from the mixed effects model; effects were divided by this SD and their magnitudes interpreted with the following scale: <0.2 , trivial; 0.2 to 0.6, small; 0.6 to 1.2 moderate and >1.2 , large (Hopkins et al., 2009). Effects were classified as unclear if the $\pm 90\%$ confidence limits crossed thresholds for substantial positive and negative values (± 0.2 standardised units) by $\geq 5\%$, otherwise the effect was deemed clear.

The minimum sample size required to detect an IRR of ≥ 1.43 (Hopkins 2010) with 80% power and a 90% confidence level was estimated to be 1107 player hours on both surfaces, or 28 equivalent matches on each surface.

Results

Injury incidence, severity and burden

Table 1 displays the exposure time recorded for each pitch type within each category of injury. Of the included matches relating to time-loss injuries, 34 were Premiership fixtures and 7 were National Cup fixtures (opposition data were not collected in three of these fixtures as they were outside of the capture remit of the England Professional Rugby Injury Surveillance Project). For data relating to abrasion injuries, 23 were Premiership fixtures and 4 were National Cup fixtures.

Table 1 near here

A total of 110 match time-loss injuries (artificial, 50; natural, 60) were reported during the study period. This equated to an injury incidence on artificial turf of 66 per 1000 player hours (90% CI: 52-83), and an injury incidence on natural grass of 73 per 1000 player hours (90% CI: 59-90). The incidence rate ratio, using natural grass as the reference category, was 0.90 (90% CI: 0.66-1.23); there was a 90% likelihood that the difference in injury incidence between playing surfaces was trivial (Fig. 1.).

Fig. 1 near here

Table 2 displays the mean and median injury severity observed on each playing surface. There was no clear difference in the mean severity of injuries sustained on the two playing surfaces. The median severity of injuries sustained on natural grass was higher than on artificial turf, although this difference was not statistically significant ($P=0.09$). This difference is likely explained by the higher incidence of minor injuries, and lower incidence of moderate injuries, sustained on the artificial turf (Table 3).

Table 2 near here

Table 3 near here

The injury burden for matches played on the artificial surface was 1362 days per 1000 player h (90% CI: 1079-1719), and for matches played on natural grass the injury burden was 1355 days per 1000 player h (90% CI: 1096-1675). The incidence rate ratio, using natural grass as the reference category, was 1.01 (90% CI: 0.73-1.38); there was a 94% likelihood that the difference in injury burden between playing surfaces was trivial (Fig. 2).

Fig. 2 near here

Cause of injury

The most common injury event on both surfaces was being tackled (Table 4). The incidence of injuries incurred through unknown events was also possibly higher on the artificial turf, whilst the incidence of injuries incurred during running was possibly lower on the artificial turf. The incidence of injuries sustained in the scrum was higher on the artificial turf (n=5) compared to natural grass (n=2), although this effect was not clear. All five of the scrum injuries incurred on the artificial surface were recorded during the 2012/13 pilot study period, with none recorded during the 2013/14 season. Once again, the small numbers negate any firm conclusions regarding these events.

Table 4 near here

Nature of injury

There were no clear differences in the location or type of injuries sustained on the two playing surfaces (see Supporting Information Table S1). The most common

injury location on both surfaces was the lower limb, and the most common injury types were minor joint traumas and neural conditions. More ‘avulsion or chip fracture injuries’ were sustained on natural grass (n=5) than on artificial turf (n=0), although the small numbers negate any clear conclusions regarding this difference.

Abrasion injuries

A total of 66 abrasion injuries (artificial, 57; natural, 9) were reported during the 2013/14 season. This equated to an injury incidence of 119 per 1000 player hours (90% CI: 96-148) on artificial turf, and an injury incidence of 15 per 1000 player hours (90% CI: 9-26) on natural grass. The incidence rate ratio, using natural grass as the reference category, was 7.92 (90% CI: 4.39-14.28); there was a 100% likelihood that the incidence of abrasion injuries on artificial turf was substantially higher than on natural grass (Fig. 3).

Fig. 3 near here

The Pearson correlation coefficient for the relationship between weekly rainfall prior to the match and number of abrasion injuries was $r = -0.29$ (90% CI: -0.69-0.25, inference = ‘unclear’). Two of the abrasion injuries recorded on artificial turf resulted in time loss, with severities of 6 and 13 days. The majority of abrasions (68%) were second-degree, with 26% first-degree and 5% third-degree (most severe). The mean area of recorded abrasions was 12.0 cm² (90% CI: 9.0-15.1). Abrasions were most commonly incurred on the knee (74%), followed by the lower leg (9%), elbow (7%) and forearm (4%). The number of abrasions per position was highest in wingers (0.32 abrasions per player), centres (0.32 abrasions per player) and flankers (0.20 abrasions per player).

Muscle soreness

Reported muscle soreness from 95 players representing nine opposition teams were included in the analysis. This represents a response rate of ~70% of the total estimated population. Perceived soreness peaked on day 1 post-match and then gradually decreased (Fig. 4). Muscle soreness responses were consistently higher over the four days following a match on artificial turf in comparison to a match played on natural grass, although the magnitude of this effect was small, with effect sizes ranging from 0.26 (90% CI: 0.07-0.62) on day 1 to 0.40 (90% CI: 0.21-0.76) on day 4. The effect of the artificial surface on muscle soreness was statistically clear on each of the four days post-match.

Fig. 4 near here

Discussion

There were no clear differences in the incidence, severity or overall burden of time-loss injuries between the playing surfaces, based on thresholds set to detect moderate effects. Abrasions were substantially more common on the artificial turf, although the majority of these were minor and only two resulted in any reported time-loss from training or match play. Muscle soreness was consistently higher over the four days following a match on artificial turf in comparison to matches played on natural grass, although the magnitude of this effect was small.

Playing elite Rugby Union on an artificial surface does not appear to be associated with any substantial change in overall time-loss injury risk, which is similar to results reported for other team sports (Williams et al., 2011). However, several additional seasons of surveillance will be required before any smaller differences in overall injury risk (i.e., incidence rate ratio thresholds of 0.90 and 1.11) or variations in injury patterns may be detected. For instance, Fuller et al., (2010) reported noteworthy differences in the incidence of anterior cruciate ligament injuries and ankle injuries when playing Rugby Union on an artificial surface, although the differences were not statistically significant. Due to the relative scarcity of such injury events, considerable exposure time is required to detect any clear alterations in injury risk. Interestingly, the artificial surface was associated with a higher incidence of minor injuries (≤ 7 days) and a lower incidence of moderate injuries (8-21 days), resulting in a lower median injury severity. However, as the two injuries resulting in the greatest time-loss (183 and 134 days) were both incurred on the artificial turf, the mean severity of injuries and overall injury burden on the two surfaces was similar. A high incidence of scrum-related injuries was observed during the pilot study period, with an incidence of 36 per 1000 forward hours in comparison with a

Premiership average of 10 per 1000 forward hours in 2011/12 (Taylor et al., 2014). However, no scrum injuries were recorded on the artificial turf during the 2013/14 season, resulting in an overall incidence of 12 per 1000 player hours (from the five scrum injuries reported across the whole study period). This change in injury pattern may be purely a result of natural sampling variation, but may also be indicative of a learning effect within forwards in relation to scrum technique on artificial turf, alongside dissemination of information regarding factors such as optimal footwear choices for the surface. The nature and cause of injuries on artificial turf should be closely monitored in future seasons, in order to identify any potential differences in injury mechanisms between playing surfaces.

Abrasions were substantially more common on artificial turf in comparison with natural grass, with an average of 4.75 abrasions per match. A small negative correlation was found between the previous week's rainfall and the number of abrasion injuries recorded, although this relationship was not significant. Adding water to the surface may help to reduce skin abrasion effects, although whether this also modifies the risk of other forms of injury is currently unclear (van den Eijnde et al., 2014). Centres, wingers and flankers appear to be most at risk of abrasion injuries; the use of protective equipment (e.g. adhesive bandages, long-sleeve shirts) and skin lubricants may be of benefit in preventing abrasion injuries (van den Eijnde et al., 2014) and may be particularly useful for players in these positions. When all abrasions recorded during the pilot study are included, only two out of a total of 123 recorded abrasions resulted in any time-loss, demonstrating that acute skin injuries can be managed and treated effectively. The risk of complications, in particular infections, appears to be low in professional players (who have frequent access to medical professionals) but abrasion treatment/management information (e.g. Basler

et al., 2001) may be beneficial for youth and community level populations playing on artificial turf in order to avoid such issues.

Muscle soreness responses were consistently higher on the four days following a match on artificial turf in comparison to a match played on natural grass, although the magnitude of this effect was small. This finding is in agreement with results reported for professional soccer players (Poulos et al., 2014). Several studies have been conducted that suggest the mechanical properties of a playing surface (e.g. its stiffness and traction) influence the kinematics and kinetics of running, with associated changes in metabolic and physiological responses (Hardin et al., 2004; Kerdok et al., 2002). The playing surface may also change the nature of the game itself (e.g. running speeds, ball-in-play time and concomitant fatigue levels), as has been reported in other sports (Andersson et al., 2008; Di Michele et al., 2009; Gains et al., 2010; Norton et al., 2001).

Perceptions of muscle soreness have been shown to correlate with biochemical markers of muscle damage following exercise (Clarkson & Tremblay 1988). However, self-reported muscle soreness measures could be subject to misinterpretation of the questions being asked, as well as participant expectancy effects (McGrath et al., 2014). Additionally, the home team won eleven of the twelve matches on the artificial surface; losing has been shown to produce strong unpleasant emotional changes in rugby players (Wilson & Kerr 1999), and so this may also have contributed towards the higher muscle soreness reported by the away team following matches played on the artificial turf compared to natural grass. Given that the visiting teams' players rarely play competitive matches on an artificial surface, it may be that the unfamiliar characteristics of the playing surface resulted in

the small elevation in muscle soreness on the days following the match, which may subsequently diminish with future exposure (within several months) to the same surface due to the repeated bout effect (McHugh et al., 1999). Knowledge of how players respond to and recover from matches is important for team-sport coaches when considering the subsequent week's training and match demands (Montgomery & Hopkins 2012). Over the four days following a match on artificial turf, coaches can expect players' muscle soreness to be slightly higher in comparison to matches played on natural grass. These data may be useful for coaches when planning training and recovery protocols following fixtures played on an artificial surface.

A strength of the current study was its prospective cohort design and elite Rugby Union population, which provided robust and novel data relating to the influence of artificial playing surfaces upon injury risk in this setting. In addition, a non-time-loss definition was used for recording abrasion injuries, which helped to address the underreporting of such injuries (Ekstrand et al., 2006).

A limitation of the current study is that an inter-cohort comparison between teams playing on artificial turf at their home facility versus teams playing on natural grass at their home facility was not possible, due to the fact that only one Premiership team had an artificial surface installed during the study period. In a study involving professional football teams (n=32), no substantial differences were found in acute injury rates between playing surfaces at the individual player level, but it was revealed that teams who played on artificial turf at their home facility had higher rates of overuse and acute training injuries compared with teams that played their home matches on natural grass (Kristenson et al., 2013). As the number of professional Rugby Union teams using artificial surfaces at their home facility

increases (the number of teams with an artificial turf pitch installed has already increased to three since the beginning of the current study period), such analyses will be possible and will allow for a more complete understanding of how artificial playing surfaces influence injury risk in this population. In addition, exposure to artificial playing surfaces during training activities will be recorded in this population in future seasons, to allow investigation of their influence upon training injury risk.

Perspectives

The present study was the first to investigate the use of an artificial playing surface in an elite Rugby Union setting. There were no clear differences in the incidence, severity or overall burden of time-loss injuries between the playing surfaces. However, due to the size of the sample population, further surveillance is required before inferences regarding specific injury diagnoses, for example ACL injury risk, and smaller differences in overall injury risk between the playing surfaces can be made. Abrasions were substantially more common on the artificial turf, although the majority of these were minor and only two resulted in any reported time-loss from training or match play, therefore the abrasions incurred on artificial turf can generally be appropriately managed to reduce impact. Muscle soreness was consistently higher over the four days following a match on artificial turf in comparison to matches played on natural grass, although the magnitude of this effect was small. These results provide evidence to support the current and future use of artificial playing surfaces in elite Rugby Union, so long as continued surveillance is undertaken to allow analyses of specific injury diagnoses and smaller overall differences in injury risk to be carried out. Moreover, the long term risks associated with playing Rugby Union on artificial turf warrants investigation.

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Tables

Table 1. Player exposure times [h] recorded for each category of injury

	Time-loss injury player hours (number of equivalent matches)	Abrasion injury player hours (number of equivalent matches)
Artificial turf	760 (19)	480 (12)
Natural grass	820 (20.5)	600 (15)
Total	1580 (39.5)	1080 (27)

Table 2. Severity of time-loss injuries [days] sustained on artificial turf and natural grass

	Mean \pm 90% CL	Observed SD	Median \pm 90% CL
Artificial turf	20.7 \pm 8.2	34.5	6.5 \pm 2.0
Natural grass	18.5 \pm 9.8	23.0	11.5 \pm 3.0

Table 3. Incidence of time-loss injuries [injuries per 1000 player h] on artificial turf and natural grass as a function of injury severity, with rate ratio (using natural grass as reference) and inference regarding the magnitude of difference

	Artificial turf (90% CI)	Natural grass (90% CI)	Rate ratio (90% CI)	Inference
Minor (2-7 days)	34.2 (24.8-47.2)	21.4 (14.5-31.6)	1.6 (1.0-2.7)	Artificial possibly >
Moderate (8-21 days)	17.1 (10.8-27.0)	34.5 (25.4-46.9)	0.5 (0.3-0.9)	Artificial likely <
Severe (> 21 days)	14.5 (8.8-23.8)	15.5 (9.8-24.4)	0.9 (0.5-1.8)	Unclear

Table 4. Incidence of time-loss injuries [injuries per 1000 player h] on artificial turf and natural grass as a function of inciting event, with rate ratio (using natural grass as reference) and inference regarding the magnitude of difference

Cause of injury	Artificial turf (90% CI)	Natural grass (90% CI)	Rate ratio (90% CI)	Inference
Collision (accidental)	5.3 (2.3-12.0)	8.3 (4.5-15.5)	0.6 (0.2-1.8)	Unclear
Collision (non accidental)	1.3 (0.3-6.8)	2.4 (0.7-7.6)	0.5 (0.1-3.9)	Unclear
Contact with ground	2.6 (0.8-8.4)	-	-	Unclear
First set scrum [†]	12.3 (5.9-25.7)	4.6 (1.4-14.6)	2.7 (0.7-10.7)	Unclear
Lineout [†]	2.5 (0.5-12.8)	2.3 (0.4-11.8)	1.1 (0.1-11.3)	Unclear
Maul	-	1.2 (0.2-6.2)	-	Unclear
Ruck	3.9 (1.5-10.2)	6.0 (2.9-12.4)	0.7 (0.2-2.2)	Unclear
Running	5.3 (2.3-12.0)	10.7 (6.2-18.5)	0.5 (0.2-1.3)	Artificial possible <
Tackled	15.8 (9.8-25.4)	20.2 (13.6-30.2)	0.8 (0.4-1.5)	Unclear
Tackling	10.5 (5.9-18.8)	11.9 (7.1-20.0)	0.9 (0.4-1.9)	Unclear
Unknown	13.2 (7.8-22.1)	7.1 (3.6-14.0)	1.9 (0.8-4.4)	Artificial possibly >

[†]Only forwards were considered to be 'at risk' during these events.

Figure legends

Fig. 1. Incidence rate ratio (with 90% CI) of time-loss injuries, using natural grass as the reference group. Dotted lines represent thresholds for smallest worthwhile difference (0.70 and 1.43). Data labels give % likelihood that the effect is beneficial | trivial | harmful.

Fig. 2. Injury incidence and severity for time-loss injuries incurred on artificial turf and natural grass. Vertical and horizontal bars represent 90% CIs for severity and incidence, respectively.

Fig. 3. Incidence rate ratio (with 90% CI) of abrasion injuries, using natural grass as the reference group. Dotted lines represent thresholds for smallest worthwhile difference (0.5 and 2.0). Data labels give % likelihood that the effect is beneficial | trivial | harmful.

Fig. 4. Reported general muscle soreness over the 4 days following a match on artificial turf (circles) and natural grass (triangles). Values are means, bars are 90% CI. *, clear and substantial difference between surfaces.